Wound Ballistics Workshop Presentations

FBI Academy
January 19-22, 1993

1993 Wound Ballistics Seminar
FBI Academy, Quantico, Virginia

The 1993 Wound Ballistics Seminar was held to (1) assess the validity of findings and recommendations resulting from the 1987 Workshop, and (2) make recommendations for future research in this area.

Participants were respected subject matter experts in the following disciplines:

- Trauma medicine
- Forensic pathology
- Engineering
- "Laboratory" analysis of firearms and ammunition
- Ballistics
- Firearms training
- Law

This year's attendees, particularly those involved in trauma medicine and forensic pathology, affirmed the validity of the earlier Wound Ballistics Workshop. Their consensus opinion was:

- It is virtually impossible to predict how a human being will react to being shot.
- **Shot placement is critical** and is dependent upon good training (there is no "magic" bullet).
- The only thing an officer can depend upon to produce **rapid, reliable incapacitation** with a handgun is the infliction of trauma so severe as to:
  - Totally disrupt the central nervous system.

This year's attendees also reaffirmed the importance of continued research in wound ballistics and made the following recommendations:

- The creation of a national "clearing house" for the collection, analysis, and distribution of information about wound ballistics.

- The adoption of new, universal data collection protocols involving collaboration between trauma surgeons, forensic pathologists, and firearms examiners.

- The inclusion of survivor or witness interviews, when possible, to build a data base on how human beings react to being shot and to correlate this information with the location/severity of wounds and the rounds used in the shooting.

The opinions and recommendations of the participants, while relevant to the study of wound ballistics, may not necessarily represent the views of everyone in the greater scientific or law enforcement community.

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Summary of Remarks by
Dr. Ed Lane
General Surgeon
Fairfax Hospital, Fairfax, Virginia
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Dr. Ed Lane, Orthopedic Surgeon (specializing in trauma care), Fairfax Hospital, Fairfax, Virginia, advised that he was going to discuss emergency room procedures and what is done to treat trauma patients when they arrive at the hospital. He also discussed patient activity at the time of arrival and whether or not they were capable of continued voluntary functions. Dr. Lane advised that the extend of tissue damage determines what the trauma team needs to do to improve/restore function, or to maintain viability of the body part which is injured. Dr. Lane showed a photograph of a patient with an ice pick protruding from his head. The patient was functioning fine but was a bit abusive while in the emergency room. He advised that many patients are not cooperative because their injuries were inflicted by police, or they were the victims of violent crime.

Dr. Lane advised that he sees two types of handgun injuries:

1. **Low velocity** injuries - person is functioning, normally abusive, and not totally incapacitated.

2. **High velocity injuries** - increased velocity even with smaller projectiles, causes more devastating injuries. Incapacitation tests have been reported on live animals (shots were fired into the lung and liver of a live pig and, finally, a hammer was used) and the animal functioned through the experiment.

He advised that "one shot" will not necessarily "stop" an individual from carrying out voluntary activities.

Dr. Lane advised that the shape of a bullet makes a tremendous difference in the effect on body tissues damaged which, in turn, affects the treatment of the wound. The more damage caused by a projectile, the more aggressive the treatment must be to restore/prevent loss of tissue and infection. Wounding effects on soft tissue are caused by: (1) Cutting, (2) Temporary cavitation, (3) Compression of tissues, and (4) Healing of the wound. An exception to the rule is when the wound is near central nervous system structures. The effect of transmitted force is often enough to bruise the brain stem or cervical spine, which will significantly effect central nervous system functions.

Dr. Lane showed the following examples of wounds and discussed the functioning capabilities of the patients involved. He advised that it is often more disruptive to remove a projectile than to leave it in the body.

1. Glazer round through foot - significant problems healing due to tissue damage. Patient walked into the emergency room and had full function.

2. .22 round through leg (point blank) - low velocity wound, advised to go home, patient functioning. A second look, however, revealed that pieces of the man's jeans were within the wound cavity. Severe infection would have occurred if the projectile and material had not been removed.

3. 9mm in arm - complete functioning, patient drove self to hospital, some discomfort, complete function of arm after treatment.

4. .357 mag. through leg - metal rod inserted to repair, infection occurred which caused problems.

5. Shotgun blast to forearm - no functioning of arm, severe tissue damage.

Dr. Lane advised that delayed healing was often associated with loss of muscle tissue. He advised that a shotgun fired point blank can cause severe damage to bones, loss of nerves (causing loss of function), and may lead to the amputation of the limb. Another example cited was **a female with a shotgun blast to the head, who survived for several days but died due to infection** caused by the wound.

Gelatin/Femur Demonstration Test 9mm/.45 ACP, 2/11/93

Dr. Lane presented a video showing the varied effects of projectiles in the test medium. Dr. Lane and Ted Hollabaugh, Firearms Training Unit, Ammunition Testing Facility, conducted these tests using 8 1/2" blocks of 10% ballistic gelatin with a swine femur inserted into the block. He advised that swine bone is similar to human bone, and that it is easy to use within the gel blocks. Each type of ammunition was fired twice into the gelatin, once into the upper portion of the femur (a) and again into the lower portion of the femur (b) which is thinner.

He advised that while the video is interesting, each viewer must draw their own conclusions. Some examples of his test results follow:

1 (a) 9mm
115 gr.
Hollow point bullet (plated)
Velocity: 1198 FPS
Penetration: 6 1/2"
Recovered weight: 109.7 gr.
Results: soft tissue injury, fragments off of bone, no exit

1 (b) 9mm
115 gr.
Hollow point bullet (plated)
Velocity: 1198 FPS
Penetration: 7 1/2"
Recovered weight: 107.5 gr.
Results: soft tissue injury, fragments off of bone, no exit

2 (a) 9mm
147 gr.
Jacketed Hollow point - Subsonic
Velocity: 948 FPS
Penetration: 3 1/2"
Recovered weight: 137.4 gr.
Results: did not penetrate, but did damage bone

2 (b) 9mm
147 gr.
Jacketed Hollow point - Subsonic
Velocity: 948 FPS
Penetration: 5 1/2"
Recovered weight: 140.2 gr.
Results: penetrated bone

3 (a) 9mm
115 gr.
Jacketed Hollow point - sonic
Velocity: 1092 FPS
Penetration: 5 3/4"
Recovered weight: 101.6 gr.
Results: penetrated bone

3 (b) 9mm
115 gr.
Jacketed Hollow point - sonic
Velocity: 1092 FPS
Penetration: 3 1/2"
Recovered weight: 101.3 gr.
Results: no penetration of bone

4 (a) .45 ACP
230 gr.
Jacketed Hollow point
Velocity: 849 FPS
Penetration: 7 5/8"
Recovered weight: 228.0 gr.
Results: excellent penetration, significant damage to bone

4 (b) .45 ACP
230 gr.
Jacketed Hollow point
Velocity: 849 FPS
Penetration: 8 1/4"
Recovered weight: 213.8 gr.
Results: significant debris from bone and exit (only projectile that went **through** bone)

Dr. Lane advised that there was more obvious injury on the bones shot with the two (2) .45 caliber bullets than with the three (3) 9mm bullets.

Bone Damage Evaluation

Dr. Lane used slides to demonstrate the various effects caused to the bone using the above ammunition. The slides showed the ways in which the rounds affected the bones and also the configuration of the bullet when removed from the gelatin.

Summary of Remarks by
Dr. Mark G. McKenney
General Surgeon
Ryder Hospital, Miami, Florida
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Dr. Mark G. McKenney, General Surgeon (specializing in trauma and critical care), Ryder Hospital, Miami, Florida, advised that Ryder Hospital is a University of Miami facility which serves Dade County, Florida, and is dedicated to treating severe trauma injuries. All life-threatening gunshot wounds are treated at this hospital. Other forms of trauma are treated at Ryder; however, gunshot wounds are the most common form of operation performed at his facility. Patients are brought to Ryder via ambulance or helicopter, but initial treatment is generally started at the crime scene by Emergency Treatment Specialists at the direction of a doctor. A Shock Trauma Unit Team composed of two nurses, two aides, two junior surgical residents, two senior surgical residents, a secretary, and an attending surgeon treat patients upon arrival at Ryder. Dr. McKenney advised that transportation time to the hospital is critical and that there is a "Golden Hour" which is vital to the successful treatment of trauma patients. The "Trauma Triage Criteria" for Ryder is as follows:

1. Blood pressure of < 90.
2. Glasgow Coma Scale < or = 12.
3. Paralysis
4. Major burns
5. Penetrating trauma to head, neck, chest, abdomen, or groin.
6. Injury where there is a high incident of "suspicion" (paramedic's judgement).

Once the patient arrives at the hospital, the trauma team immediately resolves concerns about the "A B Cs" (Airway, Breathing, Circulation). At Ryder, treatment in the "Golden Hour" includes getting the patient stabilized, getting bleeding under control, and treating the injured area. Since the emergency room and operating room are both on the same floor at Ryder, minimal time is spent transporting the patient between units. The ABCs are listed in the order which a patient will die from the respective problem if not treated promptly.

- A (Airway) - Is the patient able to breath? Is anything obstructing the airway?

- B (Breathing) - The lungs are expanding and oxygenating the patient's blood.

- C (Circulation) - The patient has adequate blood pressure and pulse (determined by skin color, capillary refill, etc). Without oxygen, the patient will suffer irreversible brain damage in four minutes. After the ABCs have been checked and treated, doctors will stop bleeding and control contamination of the wound and other body systems.

Dr. McKenney stated that most deaths from gunshot wounds are secondary to "exsanguination" (bleeding to death). In addition to loss of blood, patients often go into shock. Shock is the result of "inadequate tissue perfusion" that prohibits the normal flow of oxygenated blood to various parts of the body. Since the brain contains the most oxygen-sensitive tissue in the body, mental functions start to deteriorate rapidly when a person goes into shock.

There are different types of shock:

- Hypovolemic
- Distributive
- Obstructive
- Cardiogenic

Hypovolemic (aka Hemorragic), caused by low blood volume, is the type of shock most common with gunshot wounds.

There are also four degrees of shock (Class 1 - 4). Characteristics associated with these classes follow:

Class 1 - Person has lost less than 750 ML (15%) of Total Blood Volume (TBV). Slightly anxious, respiration rate up a little (14-20), pulse rate up a little but less than 100, kidney output reduced slightly but functional, blood pressure near normal. Person would be able to walk or use a gun.

Class 2 - Person has lost 750-1,500 ML (15-30%) of TBV. Mildly anxious, respiration rate up (20-30), pulse rate up (greater than 100), kidney output reduced, blood pressure reduced but still near normal. Person would still be able to walk or use a gun.

Class 3 - Serious situation. Person has lost more than 1,500 ML (30%) or more TBV. Confused and anxious, respiration rate up (30-40), pulse rate up (greater than 120), kidney output greatly reduced, blood pressure reduced. A person may or may not be able to carry out voluntary actions, e.g., shoot a gun, walk, etc.

Class 4 - Life threatening. Person has lost 2,000 ML (40%) of TBV. They are confused and lethargic, respiration rate is greater than 35, pulse rate above 140, no kidney output, blood pressure greatly decreased. Person would not be able to carry out any serious functions that require thinking.

Dr. McKenney explained that the human body contains five liters/quarts of blood, and two L/Q (2,000 ML) is a point at which serious incapacitation takes place. There is **"not much room between incapacitation due to shock and death."** He pointed out that most patients that come into the hospital unconscious from loss of blood (in shock) do not survive.

The circulatory system's response to loss of blood is as follows: heart rate elevated, blood pressure increases as blood vessels clamp down trying to divert blood to the vital organs (brain, heart, etc.), decreased blood flow to kidneys, and limited response of the body. Physicians treat this problem with IV therapy.

In a shooting, surgeons are interested in the track of the bullet so they can assess damage and obtain the proper specialist to treat the wound. In head and spine wounds a neurosurgeon is needed, while an orthopedic surgeon is needed for wounds involving damage to bones.

Gunshot wounds are broken down into five areas:

- head
- neck
- chest
- abdomen
- extremities

With **head wounds**, the prognosis is usually not good and the patient generally dies (if the bullet penetrates into brain matter). **Neck wounds** are usually survivable. If the trachea, spinal column, or major vessels are hit, however, there is a high probability of death. **Chest wounds** are survivable if serious structures in the chest are not hit, e.g., heart, aorta, spinal column.

Dr. McKenney advised that approximately 85% of people shot in the chest who are treated by him do not require surgery. With a heart shot, victims are usually dead before they reach the hospital so trauma surgeons do not see them. Bullet wounds to the lungs usually do not require surgery and most will heal with

no complications. Bullets are often left in the body! With a bad chest wound, the patient's heart rate will be up and their blood pressure down, while with head injuries the opposite is true. Of the six patients Dr. McKenney treated for shots to the heart (they were still alive when brought to the emergency room), three left the hospital, one died of complications (pneumonia), and two died from the wound. He emphasized that the vast majority of individuals with heart wounds never reach the hospital. They are pronounced dead before they arrive at the trauma center.

Abdominal wounds usually require an operation (approximately 90%). The liver, spleen, spinal cord, kidneys, intestines, and major vessels are in the abdomen, and damage to them can be fatal if nonobvious damage is not found and treated (e.g., intestines). As in all bullet wounds, a detailed search of the damage created by the path of the bullet is required. No "missed injuries" are tolerated at Ryder.

Wounds to extremities generally do well but can result in amputations. Gunshot wounds which damage arteries of the knee, for example, require amputation about 33% of the time. Amputations of the arm or resulting from groin injuries, however, are infrequent. If an artery or vein is hit (major vessel) and direct pressure is not applied, however, a person could bleed to death. He advised that cylinders of gortex are used to replace damaged vessels.

Generally, according to Dr. McKenney, if an individual is not shot in a major vessel, they will do well if they reach the trauma center alive, even if they have sustained multiple gunshot wounds. He added, however, that if patients have been shot in two major vessels, death usually results. Early deaths from gunshot wounds are caused from **loss of blood**, while deaths from gunshot wounds that occur later are caused by **infection.**

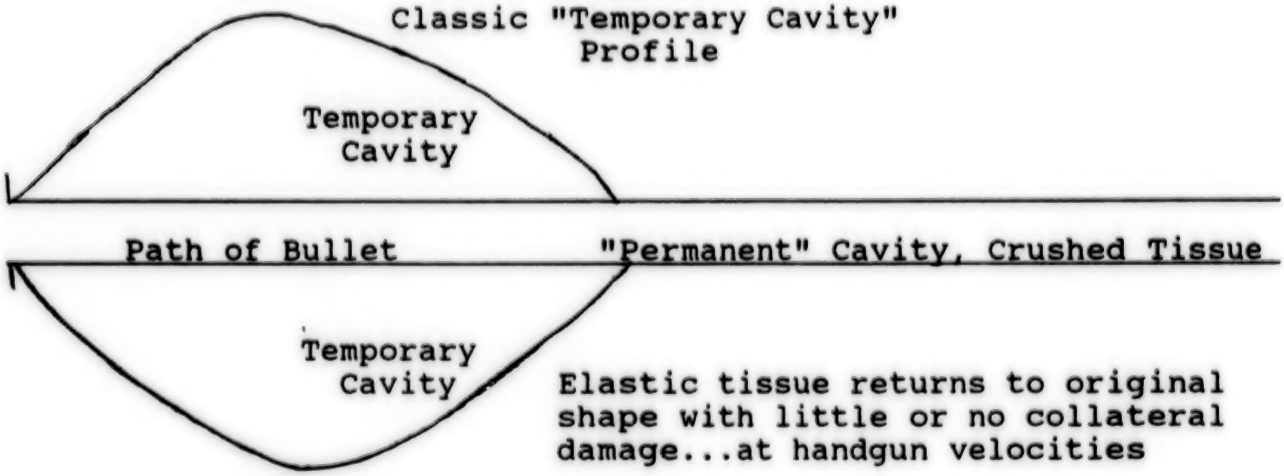
In conclusion, Dr. McKenney advised that loss of blood and contamination almost guarantees infection, but that this is often treatable. However, if **the patient bleeds to the point of unconsciousness, death often results and the time from loss of consciousness to death is often very short**. Furthermore, the quicker a victim of a gunshot wound is treated by a unit trained and equipped to handle trauma victims, the better the prognosis.

Summary of Remarks by
Dr. Martin Fackler
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/20/93

- A projectile's ability to wound and the severity of the wound caused are functions of:
  - Bullet mass
  - Bullet shape, e.g., "ball", hollow point, etc.
  - Bullet stability, e.g., yaw, pitch, etc.
  - Velocity
  - Elasticity of tissue struck, i.e., how much the tissue stretches and how well it recovers after being hit
  - What tissue is actually struck and crushed by the bullet

- At handgun velocities, most tissue generally is <u>not</u> damaged by temporary stretch or cavitation and, consequently, returns to its original shape.

- Bullet shape is a very important factor in determining the amount of temporary cavitation



- FBI "volumetric" figures only good for:
  - Computational Simplicity
  - Direct Comparison of rounds (This figure does <u>not</u> accurately represent the actual permanent cavity).

- Only sure ways to <u>quickly</u> incapacitate:
  - Destroy central nervous system, i.e., brain shot
  - Cause <u>massive</u> blood loss causing hypovolemic or "volume" shock

- FBI's rationale for requiring 12-18" penetration: major vessels lie deep in body, often <u>well</u>-protected by layers of fat, muscle and interviewing structures, e.g., arms.

- Ballistic testing conducted in swine tissue and gelatin has been validated by studies of gunshot victims (autopsies) conducted by Dr. Davis's colleagues at the Miami-Dade Medical Examiner's Office and others.

- The Platt shooting, i.e., bullet passed through arm before entering the chest, precipitated FBI interest in bullet performance and penetration. Platt's initial wounds were <u>not</u> medically fatal.

- Rapidly expanding rounds, e.g., Glaser Safety Slug, 115 grain +P+, simply do not penetrate deeply enough to damage major vessels consistently.

- Based upon extensive testing in 200-pound pigs, bullet performance (penetration) is nearly identical in muscle (very homogeneous, soft tissue) and 10 percent ballistic gelatin at 4 degrees C.

- Rounds which mushroom perfectly in clay or ducseal may <u>not</u> expand in tissue.

- Problems with "one shot stop" studies:
    - Do not differentiate between psychological and physiological causes for the "stop"
    - Do not account for why some people with insignificant injuries fall down and give up while others with gross injuries continue to fight

- Unpredictability of individual reactions to being shot illustrated by documented cases:
    - Individual who faints because he "thinks" he has been shot.
    - Individual shot <u>27 times</u> with WW Silver Tip 9mm - body described as a fragment "junk yard"
    - Jack rabbit shot 3 times with 220 Swift solid bronze bullet at 4200 fps - wounds were so small they were difficult to find

- "Potential" for tissue disruption a function of:
    - Projectile mass
    - Projectile velocity

- Realization of "potential" dependent upon:
    - Bullet construction
    - Bullet shape
    - Bullet interaction with target tissue

- Individuals with "high velocity intoxication" ignore the facts that (1) new HV rounds actually do less damage than older, slower expanding lead bullets and (2) literature documenting battlefield surgery indicates that HV rounds do not begin to do real damage until the bullet yaws.

- Consider what function "luck" plays in wound ballistics, e.g., if a "group" in the center of a silhouette target were superimposed over an anatomic diagram it would show that some shots with "excellent" target placement might miss large vessels and thus be ineffective.

- So called "Raging Controversy" about light, HV rounds versus slow, heavy rounds is a creation of the gun press.

- One must be suspect of anything in the popular gun press
    - Was test methodology scientific, objective, and accurately reported?
    - Anecdotal cases can be found to "prove" anything
    - Does the writer have a financial interest in the bullets he is recommending?

- Temporary cavitation described as a cannon ball or "big splash": versus a streamlined, non-deforming, non-yawing projectile which barely causes a splash at all.

- Dr. Vincent DiMaio, Chief Medical Examiner, San Antonio, Texas, interjected that the temporary cavity caused by handgun rounds is generally not an issue because tissue is not stretched far enough or fast enough to damage (tear) surrounding structures...fluid mechanics, "shock" wave physics issues.

- Winston Churchill: "What is obvious may not be relevant, and what is relevant may not be obvious."

- An approximation of what was discussed, but was not agreed upon was that it is impossible to determine if an isolated bullet wound was made by a 9mm, a .38 Special, or a .357 Magnum from the size of the hole. However, a .22 can certainly be differentiated from a .45 caliber hole, but a .429, .44 Special or Magnum probably cannot be separated from a .45 even on side-by-side comparison, but a .25 and .45 caliber hole probably can.

- Given handgun rounds, dilation, stretching, tearing caused by temporary cavity readily repaired by contraction, spasm and clotting; therefore, these types of collateral injuries are not an issue in handgun wounding.

- Temporary cavitation from HV rifle rounds can cause serious peripheral damage, including tearing arteries and breaking bones.

- Injuries in elastic bowels and in nonelastic (liver, heart) tissue can not be compared.

- **Shot placement and penetration are the most important factors in handgun wounding.**

- Gunshot wound studies need to be augmented by gunshot "survivor" interviews.

- Can a police officer depend upon temporary cavitation to have any wounding effect? No!

- The gun press, however, can mislead the public by leaving the "perception" that a given bullet is effective by illustrating temporary cavitation in clay or ducseal.

Forensic
Pathologists

Summary of Remarks by
Joseph H. Davis, M.D.
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Introduction

My interest in wound ballistics can be traced back to my study of Hatcher's Textbook of Firearms Identification and Evidence, First Edition (1935), which I read as a 16 year old in 1940. I remember well the days when Civil War and Spanish American War rifles were inexpensive and available without governmental interference. As a teenager, I could ride the bus in Manhattan and walk freely through Grand Central Station with a rifle purchased from Francis Bannerman and Sons, 500 Broadway.

As the '30s ended, the 220 Swift became a popular gun writer topic well beyond my fiscal ability to own and test.

World War II commenced. Popular gun journals discussed mysterious effects on very high velocity projectiles; anecdotes of deer dropping dead from a leg shot and victims of London bombings dying from high velocity peripheral injury effects. Unfortunately, these were sketchy reports, poorly documented and not supported by scientific rationale.

In an attempt to learn more, I applied for duty at the Foreign Weapons Testing Section at Aberdeen Proving Ground when the Army called up its reserves from college. I was an engineering student at Lehigh in February 1943, but the Army had better plans. I became a medic, and the only weapon I had was my own Colt Single Action 32/30 with my own ammunition!

Then the Army saw fit to send me back for engineering study at Virginia Polytechnic Institute, where one of my teachers was Julian Hatcher's brother, but he was not the Hatcher of the firearms textbook. Later, the Army decided that I should become a doctor for premedicine and sent me to Princeton, where I had the privilege of listening to Harvey fire his high velocity spheres at tissue targets. However, his work was classified and not available to me until after the Army's Wound Ballistics was published.

That brings us to our current problem with civilian wound ballistics. No civilian studies of note existed. Those of us not involved with military studies (all classified) had to rely upon popular gun journals whose authors grind out "hype" articles monthly with little scientific or statistical validity. Besides, even the military studies were not applicable to the civilian battlefield.

Medical Examiner Experience:

As a forensic pathologist for the past 37 years, initially in New Orleans and then in Miami as a medical examiner, I noted a wide diversity in civilian fatal gunshot wound patterns. They covered a gamut of weapons with changing types over the years. Some victims appeared to have dropped fairly quickly; others exerted post injury activity and still others had made it to the hospital. The nonfatal survivor patterns were not available for study.

It became clear that bullet placement was a key factor in "stopping power," a term popularized by the gun writers. Velocity considerations appeared (the .38 Special Super Vel) and were touted by the gun press. At a firearms seminar, I listened to discussions which featured the ideal handgun bullet expending its kinetic energy through rapid expansion. However, I did not observe a consistent pattern to differentiate the faster from the slower bullets caliber and type being similar. Police trainers inquired of me in reference to ammunition of choice. I was of little help in making fine distinctions, except that projectile placement was the key to "stopping power."

Then came the relative incapacitation index. It still did not create in my mind an alternative to proper bullet placement and penetration.

I became aware of problems of surgical therapy of gunshot wounds espoused by some physicians and challenged by others, chiefly Dr. Martin Fackler. Finally came the notorious FBI shootout in Miami, close to my house, which resulted in the FBI Academy Firearms Training Unit publication in 1989 entitled, Handgun Wounding Factors and Effectiveness, which seemed to be more sensible than the RII or tales from the popular gun writers. Outstanding was emphasis upon a standard depth of penetration despite intermediary targets.

However, there remained an informational hiatus. What was the actual experience in the field? Medical examiners and trauma surgeons could, in some locations, create records better suited for additional wounding studies than now exist. Such records, however, are of little help without correlative study incorporating scene circumstance and firearms technical data, a procedure not readily available to busy surgeons and medical examiners; except perhaps those in centers where the crime laboratory and the medical examiner are under one roof; Dallas and San Antonio come to mind. Key to success is interest. In Mobile, Alabama, Dr. Riddick and associates have looked at this. Some trauma surgeons did likewise.

Medical examiner autopsies, as now prepared, are ill suited for detailed study of wounding patterns, because the courts are little interested in what went on inside. They usually address issues of range, directionality, and the proper recovery of the projectile.

As a start, I would propose that we recommend an additional step in autopsy procedure, especially in torso injuries.

This is to document, by photographs and measurements, tissue disruption by the projectile as part of the routine autopsy procedure. Perhaps Dr. DiMaio might include this in his second edition of Gunshot Wounds whenever it is to be printed.

Such a procedure does not require the pathologist to know the projectile or circumstance details before the autopsy. It serves to create a document better suited to retrospective correlative study should such become a reality.

Case Examples

During an office Christmas party, an employee became involved in an altercation in which he killed three people and then hung himself when a hostage escaped. The weapon was a .44 magnum caliber, crime laboratory correlations not yet completed. Two of the victims died of chest wounds and one, a female, of a wound of the leg. Rescue efforts could not have saved her because of the prolonged hostage situation.

Victim One: The projectile pathway was through a glass window, clothes, anterior chest wall, heart, left lung, back exit, and into a wall. Photographs document a 1.7 centimeter skin wound of entrance, an anterior chest wall defect of 2.5 by 1.5 centimeters, an anterior heart defect of 10.6 by 6.6 centimeters, an exit of the heart of 6.2 by 4.5 centimeters, a 3.4 by 2.2 entrance of the left lower lobe (not pictured), and a lung exit of 2.0 by 1.1 centimeters, and a skin exit 1.7 centimeter diameter.

Victim Two: The projectile passed through clothing, anterior chest wall, right lung hilum, thoracic spine and cord. Fragments were beneath the skin of the back. Photographs reveal a 1.1 centimeter skin entrance, a 4.8 by 2.8 anterior chest wall defect and bullet fragments recovered from the skin of the back. The lung hilar disruption of right pulmonary artery, right main bronchus and superior vena cava did not lend itself to clarifying photographic documentation.

Both of these cases illustrate how simple it is for a busy medical examiner to document salient features of a wound pathway without expenditure of significant time or money. Depth of penetration, by itself, would be a simpler procedure, as long as some assessment of damage were included in the report.

Recommendations:

1. That Dr. DiMaio add this procedure to his book in the section entitled "The Autopsy Report."

2. There be chosen a few medical examiner offices to test this and its applicability to correlative study. I would volunteer Miami as one of the places to consider as we have interest, ample cases, a close working relationship with the Metro Dade Police Crime Laboratory, homicide detectives (The Dade County Police Shooting Investigation system is worthy of emulation by other jurisdictions), and an intimate relationship with a new modern trauma center across the street, whose research data abstractors are housed inside the medical examiners facilities.

Summary of Remarks by
Dr. Vincent J. M. DiMaio
Chief Medical Examiner
Director, Criminal Investigation Laboratory
San Antonio, Texas
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Dr. DiMaio presented what he termed, "Nonscientific Criteria for Selection of Weapons and Ammunition." Television and movies have presented the public with the idea that when a person is shot with almost any handgun or shotgun, the person will fly through the air and drop to the ground totally incapacitated. There are many other folktales and myths about how bullets kill and incapacitate. Unfortunately, the so-called "experts" of many law enforcement agencies make decisions about what weapons and ammunition their departments will issue based on these myths.

Another bad criteria used in weapon and ammunition selection is the effort to save money by buying inexpensive weapons. A department will purchase a weapon that is $20.00 cheaper and will breakdown after two years rather than purchase a weapon that is more expensive but will last for 20 years.

Some department heads believe their officers are "dummies." They are reluctant to purchase semiautomatic pistols to replace revolvers, because they are afraid their officers will shoot themselves or a civilian. These same administrators may also attempt to save money by allowing officers to qualify only once or twice a year.

Another criteria for weapon and ammunition selection may be what is perceived to be the "least dangerous" gun or bullet. Dr. DiMaio described **"politically correct weapons"** as those that are: (1) **Not too deadly**, (2) **Do not look scary,** and (3) **Can't fire too many bullets**. An officer may, for example, prefer to take a shotgun into a dangerous situation in an urban setting; a shotgun may not, however, be available because of a department policy restricting their use because they scare people. These are some of the ridiculous criteria used for selecting weapons and ammunition.

Dr. DiMaio posed the question, "What do we want from an ideal handgun/ammunition combination?" Three important criteria suggested were: (1) **Practicality** of the weapon, e.g., someone goes out and buys a 44 magnum at a gun show, fires a few rounds through it, then turns around and sells it at the next gun show because it is too bulky, too heavy, and has excessive recoil. Not a practical weapon; (2) **Rapid incapacitation** - The ability of

the weapon/ammunition to disable the person shot. The ideal would be a weapon or ammunition that would cause immediate incapacitation with each hit. Since this isn't possible, we must concentrate on what **weapon/ammunition combination will produce the greatest accuracy and possibility of immediate incapacitation;** and (3) **Safety to bystanders** - Preference for a round capable of penetrating deep enough in the human body to reach vital organs, yet not causing a lot of through and through shots.

The next consideration is what caliber to choose. The revolver is on the way out. It is simply not practical or realistic from the standpoint of round capacity alone. This eliminates the .38 and .357 caliber ammunition from practical consideration. The semiautomatic pistol appears to be the best choice, and there are several calibers to choose from, i.e., 9mm, 40 Smith and Wesson, 10mm, and .45 ACP.

In considering these rounds, we ask two important questions. Can a given round produce consistent-assured incapacitation? NO! Can any pistol cartridge? NO! **All pistol calibers and cartridges are a compromise between desired performance and practicality.** The ideal is a handgun with 60 rounds in a magazine, the recoil of a .22, and the stopping power of a 20mm cannon. Actually, we need to merge performance and practicality. Because of this, there are limitations on incapacitating abilities that have to be accepted. That is why 9mm, 40 Smith and Wesson, 10mm, and .45 ACP are the only calibers considered.

Factors Determining Incapacitation

1) Physiologic makeup of the individual shot - This may have nothing to do with physical makeup. Dr. DiMaio recalled two persons autopsied by him in the past. In one, a 250-pound man was shot once in the chest with a .22 short bullet and immediately dropped. In another case, a 105-pound female was shot four times in the chest with a .45 caliber weapon, took the weapon away from her assailant and killed him before she died. Physiologic makeup is not a factor that can be controlled.

2) Organs injured - If we could shoot everyone between the eyes or some other area of the central nervous system, we could all carry .22s. If we shoot someone in the spleen and someone else in the heart, the heart shot is the one more likely to be incapacitating. Theoretically, **we can influence this factor by better training** of police. In reality, this will not happen. Police agencies are reluctant to spend money on firearms training. Some agencies appear to take the opinion that it is cheaper to replace an officer every now and then than to spend

money on ammunition and training. Large numbers of officers do not receive adequate firearms training after graduating from their training academy.

The only "easy" way to increase the probability of injuring a vital organ is by increasing the number of rounds fired. This may not always be politically correct.

3) Severity of injury - determined by: Stretch injury (temporary cavity) and Crush injury.

One can increase "stretch" or temporary cavity injuries by: (1) Increasing the K.E. possessed by a bullet; (2) Increasing the loss of K.E. in tissue, or (3) A combination of both. The amount of K.E. possessed by "practical" pistol calibers is relatively limited (300-450 feet-pounds) and cannot be increased without destroying the "practicality" of a caliber. Designing bullets in these calibers to lose more K.E. is not effective, because there is only a limited amount of K.E. possessed by the bullet. You can't get more than you put in! The fact is that **temporary cavitation plays a marginal role at most in wounding with pistol bullets.** These bullets just do not posses enough K.E. to make a difference. While a bullet that loses 450 feet-pounds of K.E. in the body is statistically superior to one which loses 300 feet-pounds, this difference is too minor to be significant. During autopsies, the wounds look the same.

"Crush injury" can be enlarged by increasing the diameter of the bullet and, thus, the cross-sectional surface area. This can be accomplished by increasing the caliber, e.g., 9mm to 11mm, making the bullet "mushroom" as it traverses the body, or a combination of both.

Increasing the diameter of a bullet from 9mm to .40 caliber increases the cross-sectional surface area by 24%; from 9mm to .45 by 63%; and from 9mm to .60 by 187%.

While increasing the caliber and/or the mushrooming of a bullet increases "crush" injury, there is still the question: "Does this actually matter?"

Thus, what significant difference in incapacitation is there from being shot in the chest with a 90mm cannon round rather than a 75mm? Theoretically, the 90mm is more effective but....

At the other extreme: What is the difference between shooting an elephant with a .20-inch airgun pellet versus a .177-inch pellet?

Does an increase from 9mm to .45 to .60 produce a significant difference in incapacitation? There is no doubt that the amount of tissue damage is increased. But **tissue damage and incapacitation are not necessarily synonymous.** Even if there is an increase in incapacitation by changing caliber or bullet design, is it worth the cost and/or effort? If the increase in effectiveness attributed to changing from one round to another is only 1 or 2%, maybe the increased costs associated with the change would be better spent furnishing officers better body armor and training them to shoot more accurately.

Present test methods for evaluating ammunition involve the use of gelatin. This measures temporary cavity formation, size of wound tract, and degree of penetration. What is the significance of the results? One can use this medium to compare one cartridge to another, but people are not homogenous blocks of gelatin. Do differences in bullet performance correlate with "significant" differences in the body? Can anyone tell the difference between a 9mm and .40 caliber wound?

What about studies of actual shootings? These studies have several shortcomings: (1) Limited numbers; (2) Incomplete data, and (3) Case studies confined to fatal shootings. Thus,

Bullet A: ------→ 10 individuals killed ------→ 5 instantly incapacitated (50%)

Bullet B: ------→ 10 individuals killed ------→ 2 instantly incapacitated (20%)

Based on this above data, Bullet A is superior to Bullet B.

But what this "study" doesn't reveal is that:

Bullet A: ----→ 100 shot ----→ 10 died ----→ 10 incapacitated (5 living; 5 dead) (10%)

Bullet B: ----→ 20 shot ----→ 10 died ----→ 4 incapacitated (2 living; 2 dead) (20%)

Now B is superior to A.

You cannot make judgements with limited data!

Proposed

A prospective study of the incapacitating capability of various handgun calibers and types of ammunition.

The first problem is the definition of terms and how they are used. What is the definition of incapacitation? Instant incapacitation? Immediate incapacitation? **Head wounds are the most likely wounds to cause an incapacitating injury.** There must be a standard definition acceptable to the general public.

A prospective study must include: the living and the dead. Current studies suggest that for every person killed by a gunshot wound that three to five are treated and survive (Wounded/dead: 5:1; 3:1).

Who and what should be included in the study? (1) Forensic pathologists - to determine what actually caused death; (2) Firearms examiners - type, brand, style of ammunition used; (3) Hospital records - x-rays and personnel; and (4) Investigative reports and follow-up studies - ideally, one person is needed to follow-up on each case study; however, this is not always financially feasible.

Population to be studied: (1) Males 15-45 years - at age 15 a person is physically big enough. Today, a large number of 15 year olds are getting shot. (After age 45, too many other physical complications are present). (2) Individuals shot in thorax and/or abdomen and (3) Individuals suffering distant wounds.

Diverse geographical study to account for regional difference in types of weapons and ammunition used. Also, type of facilities available - trauma units, laboratories, forensic pathologists. There should be a form to place all of this information on or a data base available for input.

Information on wounds: (1) General location of entrance, e.g., left upper chest; (2) Organs traversed; (3) Length of wound track; (4) Penetrating versus perforating wound.

Information on weapons: (1) Type, and (2) Caliber.

Information on ammunition: (1) Brand, (2) Bullet style and weight, (3) Weight of recovered bullet, and (4) Degree of expansion.

Two very difficult but important areas to recover information on are: (1) What did the person do immediately after being shot, and (2) What did the trauma surgeon find during surgery?

Summary of Remarks by
Gregory P. Wanger, M.D.,
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
6/19-22/93

Introduction

Law enforcement has depended on firearms as the final line of protection in violent encounters. The availability of ammunition of various calibers, materials, and energy levels has lead to continuing reassessments as to the best single handgun and projectile combination for use when lethal force is required.

This paper will review data concerning handgun caliber and organ of injury and their relationship to lethality. Also discussed is the issue of incapacitation and future trends in firearms.

Caliber

The effects of caliber in firearm injuries have been of great interest to law enforcement, particularly since the adoption of the ten millimeter ammunition and Smith and Wesson Model 1076 handgun by the FBI. However, a study containing the effects of caliber in both the survivors and the dead is largely absent from the scientific literature. Most of the modern civilian publications are focused on one group; emergency room patients, surgical patients, deaths autopsied by medical examiners, etc. One has to turn to the military literature to see data concerning all the casualties. The battlefield data, however, is dominated by artillery and rifle-related injuries rather than handguns. To see a broader view of the problem, the Mobile County Medical Examiner's Firearms Data Base was reviewed[1]. In collecting this data base, an attempt to retrieve all firearms-related serious injuries and death was made using firearm examiner's, medical examiner's, hospitals, and law enforcement records for a three-year period.

Graph 1 illustrates the numbers of individuals injured and killed by firearms between 1985 to 1987 in Mobile County. Those in purple survived their injuries while those in blue died. It is apparent from this that a large number of small caliber victims survived. The large number of these survivors came as a surprise to the authors. Graph 2 illustrates the percentages of survivors and dead. Using a chi-squared trend test available in EPISTAT software, a significant increase in lethality with increasing caliber was observed.

This is more easily seen in Graph 3, in which the cases are sorted into one of three caliber categories and the percentages of lethality recalculated. There are increasing percentages of lethality with increasing caliber.

Does this indicate that caliber is the factor in determining life or death in handgun injuries? To test this hypothesis, the data concerning organ of injury was analyzed.

Organ of Injury

Using Multiple Logistic Regression analysis, available on LOGIT software, the relationship of anatomic area of injury and caliber were studied. The results are listed on Table 1.

Not surprising, wounds to the head were strongly associated with a lethal outcome. Lungs, heart, and aorta were also significant. Using this technique, the caliber of the projectile was not significant.

Does this mean caliber is not important in survival? No. It does indicate that caliber is less important than "vital" areas of the body. Obviously, any gunshot wound to the head is very serious and caliber plays a minor role. This is apparently true of the other body areas listed.

Importance to Law Enforcement

The greater significance of organ injured over the caliber would seem to indicate marksmanship should be stressed over any specific caliber consideration. This assumes, of course, sufficient penetration of the projectile to effect injury to the important organs.

As other authors have indicated, the degree of tissue damage only indirectly and unreliably relates to the more important issue of immediate incapacitation.[2,3] We have found the histories associated with these injuries to be very difficult to evaluate in regards to incapacitation. Those cases entering the medical system without any law enforcement involvement were particularly vague. (Alabama does not have any mandatory reporting of firearm injuries by the medical community). Usually, the history was, "I was walking down the street and someone shot me." No details were available as to whether they fell down, walked to a phone, etc. Retrospective studies may not be appropriate to evaluate immediate incapacitation.

There may be very real limitations on any prospective studies too. Many of the individuals shot may have reasons not to elaborate on their activities surrounding the shooting. Even if the victim was not involved in criminal activity at the time of the shooting, there may be social reasons not to be truthful about their immediate post injury activity. Young males are not likely to admit to falling down and screaming or crying in response to their wounds. Reliable witnesses may also be hard to locate. It would seem immediate incapacitation may have to be evaluated by experimental methods.

Fighting Evolution with Bullets

There are good reasons for the difficulties associated with incapacitation efforts. These are largely the result of a dependence on the mechanical effects of projectiles to produce serious physical trauma, loss of blood, shock; thereby, remotely disabling the central nervous system and ending a dangerous voluntary act. Unfortunately, as humans we have had thousands of years of selective pressure to resist this very mechanism.

Primitive man and his kin benefitted if the struggle with a wild beast continued after lethal injuries were sustained. The continued struggle might eventually kill the animal, thereby, providing the survivors with meat and hides. If the beast could not be defeated by one individual, he might gain time for others to arm themselves or flee. Probably, none of us would be here if serious penetrating injuries always caused humans to fall down and give up.

Dependence on mechanical disruption of tissue alone will always result in something less than universal immediate incapacitation. For the opposite to occur would be to swim against our evolutionary current.

Clearly, for the police officer of tomorrow to be better armed, we must explore other forms of energy to render violent persons ineffective.

Future Trends

Forms of energy other than mechanical that could be utilized include chemical, thermal, and electrical. Some have obvious drawbacks.

Chemical agents have two separate problems to overcome in order to produce incapacitation. The first is access to the central nervous system. You have to get the material into the lungs or through the skin. After that you have the problem of

circulation and penetration of the blood-brain barrier. None of this makes immediate incapacitation likely.

Thermal or radiant energy can produce rapid incapacitation but at the cost of incinerating the individual. Also the potential for igniting surrounding structures or persons would be high.

Electrical energy holds the most promise. First, the system you want to shut down, the brain, is electro-chemical. Secondly, every significant portion of the body is connected to either the evolutionary portions of the brain or the involuntary portions (autonomic system). It will be difficult for the brain to ignore a sufficient stimulus anywhere in the body and continue the malicious act. Lastly, we do not have to fight our evolution to make it work.

Primitive man's only exposure to electricity was lightning. People are struck and killed by lightning, but it is such a rare event that it has exerted no selective pressures. As a result, we have no physiologic defenses to electrical stimuli. Unlike mechanical energy, it is a form of energy we cannot ignore.

Current electrical stun devices have severe tactical limitations. It is difficult to engage multiple targets, achieve rapid firing, or use in any range other than "too close for comfort". This is because current electrical weapons are meant as alternate weapons to firearms, i.e., non-guns. What is needed is an augmentation of firearm technology with electrical energy.

This might take the form of replacing the relatively inert bullet with a more interactive projectile. This projectile would carry an electrical charge. Devices that store electrical charges are called capacitors.

The buzz word for the 1980s in reference to hollow point bullet technology was the "flying ashtray." Perhaps the buzz word for the next century will be "flying capacitors."

Photo one illustrates one crude mock-up. In it the officer is combat loading a twelve-gauge cartridge containing a charged capacitor (photo two) he has just retrieved from its charging slot in the buttstock. Upon firing, the projectile will penetrate, discharge, and render the person incapacitated without relying on deep penetration, tissue destruction, or blood loss.

It may be possible to have the projectile self-charging. Thermal semiconductors could be used that would take the heat of the gunpowder explosion and convert it to a charge on the capacitor projectile. Another approach would be to wrap the

barrel in a wire coil and charge it. As a projectile containing a coil sped through the barrel, significant electrical potential could be generated and stored in the capacitor.

Other solutions certainly are possible, as long as we view the firearm projectile as a way to get access to the central nervous system. Such approaches hold the promise of greater incapacitation and possibly less lethality.

References

[1]Riddick, L., et al, Gunshot Injuries in Mobile County, Alabama 1985-1987. Accepted for publication, December 15,1992, in The American Journal of Forensic Medicine and Pathology, Raven Press.

[2]Proceedings of the Wound Ballistic Seminar - 1987, FBI Academy, p. 2

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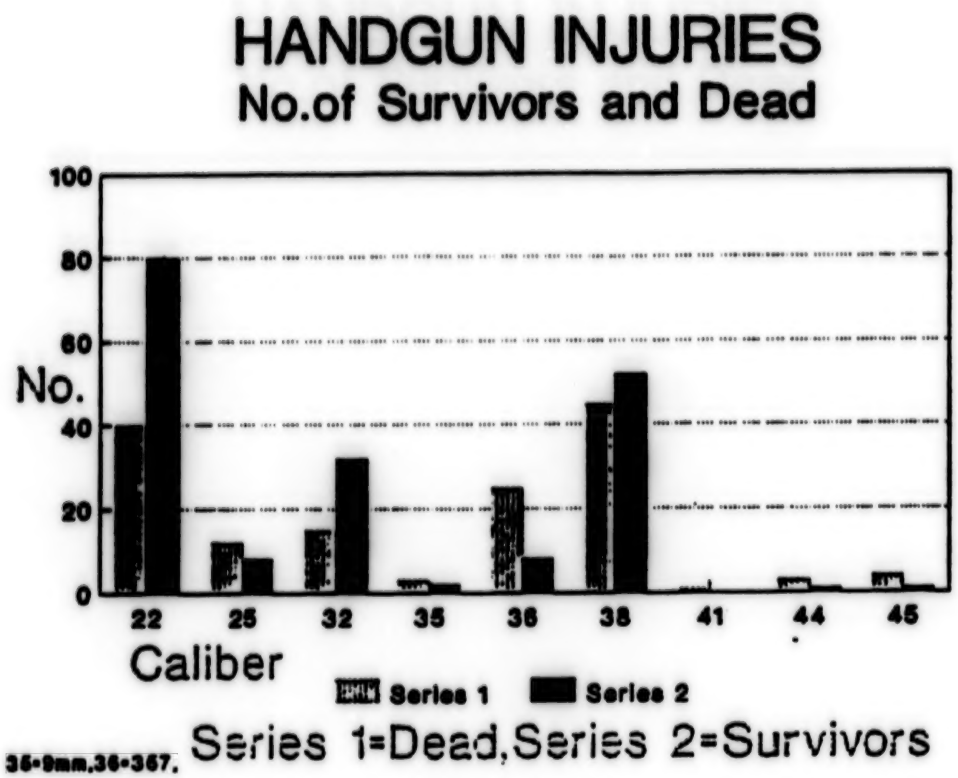
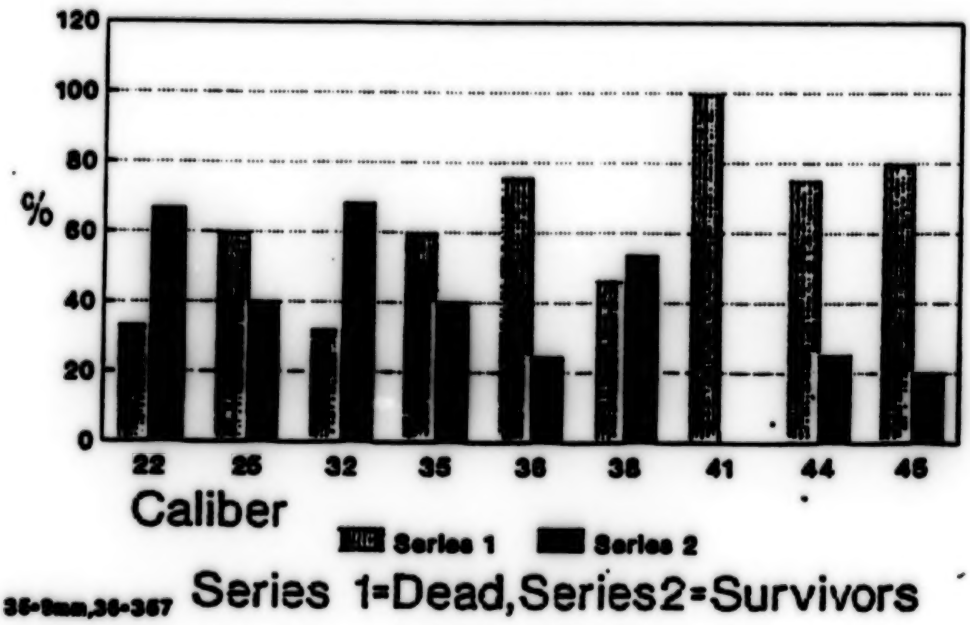
Graph 1



Graph 2



Graph 3

HANDGUN INJURIES
% Dead

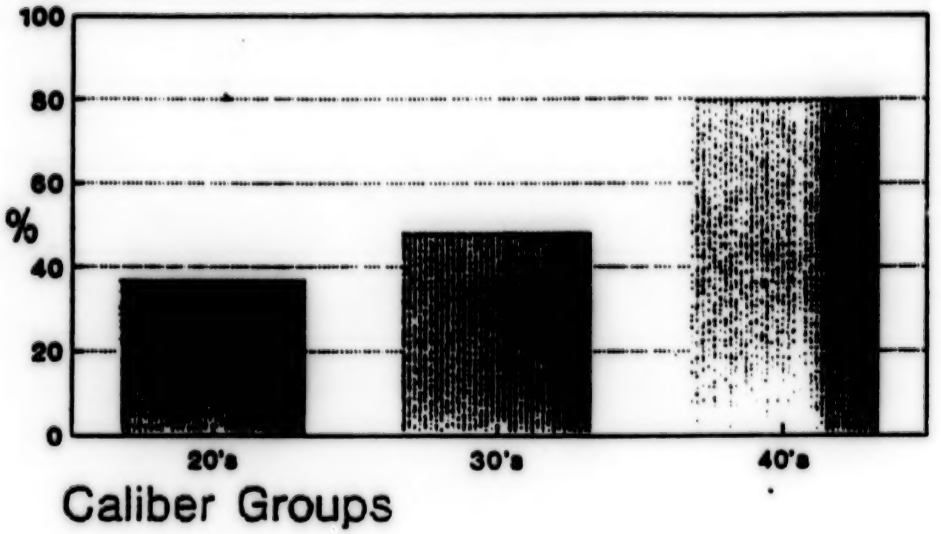


Table 1

HANDGUN INJURIES
Organ of Injury

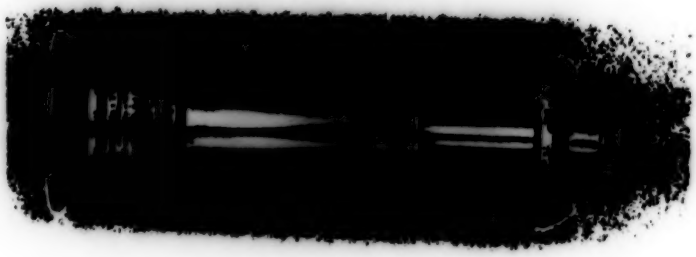
HEAD
LUNG
HEART
AORTA

Caliber not significant

In Order of Decreasing Lethality

PHOTOGRAPH ONE

PHOTOGRAPH TWO



Summary of Remarks by
John E. Smialek, M.D.
Chief Medical Examiner
State of Maryland's Forensic Medicine Center
Baltimore, Maryland
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Dr. Smialek emphasized the necessity for a study of data collected at selected study areas around the United States to correlate ammunition type and caliber with wounding capacity. The ideal facility should have a crime laboratory connected with the medical examiner's office which would facilitate the collection and correlation of information in a more efficient manner.

Dr. Smialek provided data he had collected during 1992 from the 426 gunshot cases autopsied by this office. One hundred seventy-three were single shots to the head or neck, 63 were shots to the chest, back and abdomen. One hundred five involved multiple shots to the head, neck, and chest. Information regarding the type and caliber of ammunition used was not available for these cases.

Dr. Smialek was able to obtain the following information from cases examined by his office in 1990. The ammunition used in 88 gunshot cases examined from a three-month period was as follows: .38 caliber - 38%, .25 caliber - 12%, .22 caliber - 11%, 9mm - 9%, and .32 caliber - 9%. Dr. Smialek stated his unverified observations indicate that shooting deaths in Maryland from 9mm ammunition are on the rise.

Dr. Smialek suggested the following minimum parameters for data collection relating to gunshot cases: (1) Type and caliber of ammunition, (2) Weapon, and (3) Activity of person shot immediately after the shooting.

Dr. Smialek presented two cases which, in his opinion, substantiate some aspects of the FBI Ammunition Testing Program. In one case, an officer armed with a .357 caliber revolver using jacketed .357 caliber ammunition fired into the windshield of an oncoming vehicle. At the autopsy, an unjacketed lead bullet was recovered from the chest cavity of the driver. This bullet had passed through the windshield before hitting the driver, and the jacketing had been stripped away. In the second case, Dr. Smialek showed a slide of a bullet at the point of almost exiting the body of the deceased.

The bullet was lodged in the skin opposite the entry side of the body and positioned with the base of the bullet pointing outward. This demonstrated the tumbling effect of some projectiles as they pass through soft body tissue without striking any objects outside or inside the body.

Dr. Smialek discussed the .38 caliber "Short Stop Ammunition" developed for the Sky Marshal Program. This bullet was constructed of a plastic nose covering a durable material formed into a cushion containing small pieces of birdshot. The maximum effective range of this round was about 15 feet. At up to 12 feet, the bullet would penetrate the side and plexiglass windows of a Boeing 707 aircraft and also would penetrate 6 inches into the chest cavity of an experimental subject. At 25 feet, penetration of the experimental subject dropped to 2 to 3 inches, which is not considered effective wounding capacity. This ammunition was designed to fall harmlessly at less than 200 feet.

Firearms Examiners

Summary of Remarks by
SSA Richard A. Crum
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to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

What is a firearms examiner?

Some may consider the firearms examiner, or the person who conducts firearms identification examinations, to be a closet gun nut who once worked on the street only to "retire" to the Laboratory. Some may consider the firearms examiner to be the "blacksmith" of the forensic science community.

In laboratories around the country, firearms examiners may have different responsibilities. The state or local firearms examiner in a police department may also be an armorer, medical examiner or ballistician. The duties of the firearms examiner may be very narrow or all encompassing depending on the size of the department and capabilities of the laboratory.

At present, there are ten Agents in the FBI Laboratory who are firearms examiners. We conduct forensic examinations on bullets, cartridge cases and other ammunition components and compare markings on these specimens with markings imparted by a firearm during the firing, chambering, extraction and ejection process. When we respond to crime scenes, we are concerned with the collection and preservation of physical evidence and also reconstruction of the crime scene.

How can the firearms examiner assist in the study of wound ballistics?

The firearms examiner can assist in this endeavor because of his knowledge of the evidence examined <u>in the laboratory</u> and his knowledge of the <u>crime scene</u>.

For example, the caliber of a bullet is a critical aspect of firearms identification. Caliber can be defined as the approximate diameter of the bullet. Following a shooting, a medical examiner may remove a bullet from the victim and estimate that it is a .45 caliber bullet. Can we assume that the doctor is correct in his estimate and that the bullet recovered was fired from the firearm in question? To verify the caliber of the bullet and the firearm used, the bullet must be examined by a firearms examiner who can tell you the exact caliber of the bullet, possibly identify the firearm used, and determine the type of cartridge that the bullet was commercially loaded into. This

information is vital to a credible wound ballistics study. The firearms examiner may be able to provide information regarding the bullet/ammunition used in a crime. For example, ammunition is normally sold in boxes which are marked with lot numbers (loading code). These lot numbers help identify the factory where the box was packaged, the work shift it was packaged on, and the machine used. This type of information may be important when considering terminal ballistic performance or determining where the ammunition was ultimately sold.

In the laboratory, the firearms examiner also has an opportunity to examine the weapon used to fire the bullet in a case. His examination may reveal a defect in the barrel or a condition of the barrel which may have an effect on the terminal ballistics of the bullet. For example, a badly leaded barrel could allow a bullet to yaw or tumble in flight which, in turn, would obviously effect its terminal (wound) ballistics. A thorough examination of the bullet may also reveal foreign material which may indicate that the bullet struck an intervening object prior to hitting the victim. This information, aside from providing insight into the path of the projectile (relevant when reconstructing the crime scene), is invaluable in assessing the terminal (wound) ballistics of the bullet and must be communicated to the medical examiner or person conducting a wound ballistics study. The firearms examiner also has an opportunity to examine the clothing from a victim of a shooting and can possibly determine the muzzle-to-garment distance. This distance, from the muzzle of the firearms to the victim, may be important in accessing the bullet performance and should be communicated to the person conducting the wound ballistics study.

From the crime scene perspective, the firearms examiner can, based on the location of evidence collected at the scene and bullet impact areas and bullet holes at the scene, reconstruct a shooting scene. This reconstruction may indicate that certain bullets hit intervening objects or ricocheted prior to hitting the victim. Bullet performance can obviously be effected by ricochets or intervening objects and may not be apparent upon examination of the bullet in the Laboratory. A wound ballistics study, where certain conclusions are drawn based on bullet penetration, must include and take into account this type of crime scene information which can be made available by the firearms examiner.

To assess the value of the firearms examiner to a wound ballistics study, ask yourself this question. Could valid conclusions be drawn regarding bullet terminal (wound) ballistics if forensic laboratory analysis of firearms-related evidence was not conducted and reconstruction aspects of the crime scene which would effect bullet terminal ballistics were not considered?

Paper Submitted by
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1/19-22/93

Introduction

Since the introduction of firearms, gunshot wounds are a fact of life, albeit an unfortunate one, in our modern world. The study of wound ballistics is a scientific study of projectile-tissue interaction. This study is of crucial importance to anyone who uses or depends on firearms to protect themselves. This information is also useful to forensic scientists in the evaluation of crime scenes where firearms were used.

When one considers the time, six hundred plus years, that firearms have been with us, the common assumption would be that firearms injuries are well understood and the basis of wound ballistics are well established. Unfortunately, this assumption is incorrect, as probably no scientific field today contains more misinformation about the mechanisms of gunshot wounds than the science of wound ballistics.

Numerous "war stories" and a great deal of folklore exists about gunshot wounds. The firearms literature is replete with erroneous assumptions and pseudoscientific speculation which result in further misunderstanding. An overwhelming volume of contradictory articles written about firearms effectiveness have been published in medical journals, law enforcement publications, and firearms magazines. Many of these articles purport to explain the effects of penetrating missiles on the body. Unfortunately, the majority of these articles are written by unqualified authors who have no formal training in science, do not understand the scientific method, and are not beyond proposing their own pet theories without the benefit of any supporting data to back-up their opinions. Some of the worst offenders are the firearms magazines, who continue to publish wound ballistics articles by authors who have no real expertise in the area and, in fact, are nothing but ammunition salesmen. "Definitive" books are also published without the benefit of peer review or the publication of the original data, and are allowed into publication fraught with errors, only to confuse and mislead the reader.

The first step that must be taken by the popular firearms media is establishing a process of peer review before publication. This can be done by simply creating an "Editorial Board." Many qualified experts exist in the scientific arena and should be used to review any article for errors or concepts not consistent with established facts before publication acceptance. Until this is done, we shall continue to read articles that try to convince the reader that "one-shot stops" can actually be predicted to the first decimal point. Authors that state that a certain bullet is 89.6% effective in causing a "one-shot stop" have a serious misunderstanding of wound ballistics and the flight/fight syndrome. By publishing these figures, these "authors" are spreading the worst kind of misinformation. We must expose and eliminate meaningless terms such as "stopping power," "shocking power," "energy dump," knockdown power," and other nonsense terms and consign them to the terminology dustbin of hollow and meaningless patter.

Incapacitation Factors for Handgun Bullets

In handgun missile wounds, incapacitation is caused by two factors: (1) psychological incapacitation, and (2) physiological incapacitation.

Psychological Incapacitation

In the area of psychological incapacitation, or what I like to call the "Oh my God, I've been shot" syndrome, incapacitation is a somewhat unpredictable thing. Human reaction to being shot may span from complete indifference to the wound to total incapacitation, even in absence of a gunshot wound. It is for this very reason that any attempts of incapacitation, predictably by percent effectiveness figures, stretches credulity as to the understanding of that author's understanding of the flight/fight syndrome and the effects of gunshot wounds on the human psyche. Even in shootings where missile wounds have identical wound paths with the same organs hit in two different individuals, the reaction of the two shooting victims can be completely dissimilar. The person shot might stop the actions that caused them to be shot, they might drop and call for an ambulance, they may run away, or may fight the person that has just shot him. Strong emotions such as anger, rage, hate, and the basic survival instincts can influence an individual's response to being shot. Since pain is often initially absent following injury, the person may not even know that he has been shot and will not react to the wound. Also, preconceived notions of how people should act when shot, subconsciously ingrained from the entertainment industry, can affect the response to being

shot. Throw in the effects of drugs and alcohol and what will happen is frankly unpredictable. As such, bullet effectiveness percentages are inconsistent with this reality.

Physiological Incapacitation

The wounding mechanisms of the penetrating missile are twofold. First, the missile crushes and destroys tissue as it passes through the target. The space once occupied by this pulped tissue is called the permanent cavity. This permanent cavity is quite simply the hole left by the passage of the missile, and size or volume speaks to the flow of blood that will occur with this kind of wound. The formation of this cavity is reasonably predictable. The second mechanism is the temporary cavity and is the lateral transient dispersion of tissue from the wound track caused by the centrifugally driven compression wave and is velocity, shape, and mass related. The tissue that is stretched can be damaged if the rate of expansion or size of the cavity exceeds the elastic limits of the tissue affected. At the majority of handgun velocities, temporary cavitation is simply not a factor in elastic tissue. Nonelastic tissues, such as the liver, can be affected if the in-tissue velocities are sufficiently high enough. The damage due to temporary cavitation at handgun velocities cannot be counted upon as a reliable wounding mechanism. The effects of the temporary cavity are extremely variable and erratic to nonexistent. Only wounds caused by the permanent cavity will be the major wound component at handgun velocities.

All projectiles that penetrate the body can only disrupt soft tissue by these two wounding mechanisms. Missile wounds differ in the location and amount of crushed and stretched tissue. The relative contribution by each of these mechanisms depends on the physical characteristics of the bullet. One must consider the variables of its diameter, weight, shape, construction, sectional density, and velocity. The interactions of these variables contrasted with the type of tissue with which the missile interacts will determine the wound cavity and the amount of blood flow.

Physiological incapacitation can be separated into two categories. For a lack of better terms, the first type is a "Type One" or a Central Nervous System (CNS) disruption. In this incapacitation, caliber is not a factor other than that the missile has sufficient penetration to reach a vital CNS structure. In effect, a .22 Short Rim Fire in the back of the head is as effective as a .44 Magnum. Both will give the same result. In a Type One incapacitation, arguments as to best caliber or firearms are fruitless endeavors.

"Type Two" incapacitations are non-CNS hits. In this type of wound, the size and location of the wound are of paramount importance. The rate of incapacitation is directly proportional to the rate of blood flow and the organs or structures hit. The effectiveness of this type of wound is related to the depth of penetration and the location of the shot. The key words here are **placement** and **penetration**. Larger diameter calibers are more effective than smaller calibers. High sectional density bullets are more effective than low sectional density bullets. Bullets that expand are better than nonexpanding bullets, especially when their modified sectional density remains high. Because of this, it is best to start out with the heaviest weight bullet the caliber can handle without excessive chamber pressure. This will give you a bullet with the highest sectional density possible. Fire it at a velocity that will give reliable expansion in calibrated ballistic gelatin. Put this in the right location, anatomically, and you will have the best chance for an effective Type Two incapacitation.

Using this kind of construction, the bullet in a human target should give a reliable penetration depth of approximately 12 to 13 inches. Considering the range of variation that will exist due to different tissue densities in the human target, this is a good average to seek. Bullet construction should allow expansion at low velocities. This gives a lower recoil impulse, giving the shooter more time to get the sights back on target. Also, the shooter may be more competent with a low recoiling firearm/ammunition combination.

Terminal Performance Factors

In selecting self-defense ammunition, several factors must be considered.

1. Handgun bullets should reliably penetrate to 12 to 14 inches without fragmentation or core/jacket separation. Weight retention should be at least 95% of the design weight.

2. Penetration testing must be done with properly prepared and calibrated 10% 4 degree C ordnance gelatin to determine penetration and expansion.

3. Expansion characteristics should not only consider expansion diameters but the remaining length of the expanded projectile. This expansion ratio represents the modified sectional density of the missile. This ratio can be calculated for each bullet by dividing the expanded diameter by the remaining length and plotting this graphically as

expansion ratio versus missile penetration. Over-expanded missiles will result in reduced penetration as will under-expanded missiles result in over-penetration. There is a fine balance that must be met in bullet design for an expanding missile with deep penetrating characteristics.

Conclusion

Effective bullets are a product of good design and a critical understanding of their effect on living tissue. The best designs cannot be effective if they are not placed properly by the shooter. Whatever you choose, 9mm, .40 Smith and Wesson, or .45 ACP, choose a reliable expanding design that will penetrate approximately 13 inches. In the short term, the caliber really is not that important. In the long term, the larger the caliber the more effective; however, I suggest that with proper bullet selection the differences will be shown to be slight. The bullet weights which will give the greatest advantage are the 147 grain hollow points in 9mm, 180 grain hollow points in .40 Smith and Wesson, and 230 grain hollow points in .45 ACP, all driven at the lowest velocity possible and still meeting the goals of reliable expansion and approximately a 13-inch penetration in calibrated gelatin. The weight of the bullet is more important than the caliber, and the higher sectional density bullets will be shown to be the most effective. Place these bullets in a reliable firearm that you trust that fits your shooting skills, and practice, practice, practice. PLACEMENT AND PENETRATION are the keys to a successful end to an armed confrontation.

Summary of Remarks by
Dr. Irving Stone
Dallas Institute of Forensic Science
Dallas, Texas
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Dr. Stone advised that the Dallas Institute of Forensic Science performs forensic examinations for the City and County of Dallas, Texas, as well as approximately 40 surrounding counties. He indicated that the Institute is not considered a law enforcement entity nor are its employees sworn law enforcement officers.

Dr. Stone presented a case involving the new "Black Talon" round. He indicated that there did not appear to be any perceptible difference in the wound track with the Black Talon, although subsequent discussion revealed that cutting could occur with this round, especially if the cutting surfaces of the claws came in contact with veins, arteries, or intestinal tissue.

A second case was described by Dr. Stone which involved a .45 caliber gunshot. The question arising from both of these cases was, "Is there a difference in caliber between the first case and second case as viewed from a medical examiner's viewpoint?" The overwhelming answer to this question is: "You can't tell!" Entrance wounds look very much the same, and one cannot tell by looking at wound track comparisons. Once the bullet hits anything other than soft tissue - ALL BETS ARE OFF! It's a fact of life that these bullets frequently don't expand. By looking around the wound track, a person cannot distinguish the effects of tissue cutting caused by one particular bullet over another. This cannot be determined with the naked eye.

In instances where the effects of tissue cutting in the wound track were observed, these were noted by medical examiners/ firearms examiners who had a vested interest in looking for these types of wound characteristics. Dr. Stone described other wounds that can be extremely deceiving unless details of the shooting are known. In particular, he described the stellate wounds that appear when a projectile strikes bone that is covered by a thin layer of tissue. This may appear as a close-contact wound, although the weapon was actually some distance away.

Responsibilities of the Firearms Examiner:

The responsibilities of firearms examiners include: (1) law enforcement agencies, 2) forensic science support, and (3) district attorneys.

Role in Support of Law Enforcement Agencies:

- Arrives on the scene and locates the officers involved.
- Notifies preselected persons in the law enforcement agency.
- Immediately separates officers and witnesses.
- Becomes involved in activities of the Physical Evidence Squad and detectives.
- Special Investigation Unit (SIU) detectives arrive and become involved.

During this same time, there are two parallel lines of investigation being conducted.

1. By SIU to investigate any violations of criminal laws.
2. By Internal Affairs Division to determine if actions taken by the officers involved were within departmental policy guidelines.

At the crime scene:

- Witnesses/officers are separated.
- The officer's weapon is taken and another of same caliber/make is reissued.
- Rounds are counted.
- Weapons are checked to see what they are loaded with (type of ammunition, number of rounds, etc.).
- Backup weapons are checked.
- Witnesses are questioned.
- A walk-through is conducted.
- Public works crews may be used to survey area.

Role in Support of Forensic Scientists:

- Prevents alteration of shooting scene to assure no coverup occurs.

- Ensures proper recognition, collection, and preservation of physical evidence.

- When appropriate, visits hospital to examine wounds or to assure collection of proper specimens.

- Ensures priority handling of key evidence.

Support of Local Prosecutors:

- Every officer-involved shooting goes to the grand jury. Grand jury preparation involves review all witness statements, reports, laboratory and medical data, hospital reports, etc.

- The public works survey is heavily relied upon because each case is considered a civil case, and several years down the road the crime scene may change (growing of shrubs and trees, additions to buildings/roads, etc.)

Dr. Stone concluded by describing the investigative team that is operational in the Dallas area and responds to all police-involved shootings. This team has enjoyed great success in criminal investigations because of its responsiveness to the needs of the law enforcement, scientific, and legal communities affected.

Firearms Instructors

Summary of Remarks by
Sergeant Steve Campbell
Firearms Staff of the Louisiana State Police
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Sergeant Campbell predicated his presentation with the observation that it has been the experience of his agency that the information presented in the 1987 Wound Ballistics Workshop and the subsequent ammunition tests are valid, and that the 147 grain 9mm is an effective round for police use. He felt that this information should be widely disseminated because there are no facilities other than the FBI Academy that can conduct this type of research, with the exception of the California Highway Patrol. He felt that it was incumbent upon groups like the Wound Ballistics Seminar to promulgate their findings to help police departments from being misled by spurious information that routinely appears in gun magazines concerning the wounding capabilities of available 9mm ammunition.

Sergeant Campbell then cited two cases that involved Louisiana State Policemen. The first case involved an incident where a male subject was shot one time in the soft tissue of the upper arm, the triceps. The round exited the arm and entered the chest. This round was a 147 grain 9mm Hydroshock fired from a Sig Sauer P226. Sergeant Campbell stated that the subject dropped immediately upon being hit, even though no vital organs or the central nervous system had been damaged. He referred to this incident as an example of "psychological incapacitation."

The second case studied involved a hostage situation where the subject, an intoxicated male, was holding a young child hostage. This subject was shot from a distance of 13 feet, with a 147 grain 9mm Hydroshock fired from a Sig Sauer P226.

The projectile entered the subject just under his left ear at the jaw juncture and traversed the neck, coming to rest just behind the right jaw. When the recovered projectile was weighed, it was determined to weigh 138 grains. Sergeant Campbell cited this as excellent weight retention.

Sergeant Campbell reiterated the necessity for the information gathered during the Wound Ballistic Seminars to be disseminated to police agencies throughout the country.

Summary of Remarks by
Sergeant Michael Dunlap
Range Master - Amarillo, Texas Police Department
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Sergeant Dunlap presented a case study of a shooting at Amarillo in 1980. This incident involved a 46-year-old male subject and three officers.

The subject, using a tire iron as a weapon, attacked the three officers at close quarters. Forced to use their weapons, the officers inflicted 28 wounds to the subject. Of 28 rounds that struck the subject, 20 exited his body. Sergeant Dunlap stated that the bullets did not do what they were expected to do.

The officer that initially engaged the subject fired one round from a revolver, which he said he observed strike the subject in the chest. Seeing this shot have no effect, he fired three more, again with no apparent effect. He then fired his two remaining rounds.

At this time, the officer remembers two rounds being fired from behind him, and one from another unknown location. At this point, the subject fell. The two rounds fired from behind him were later determined to be from a .41 magnum utilizing 210 grain soft point projectiles which struck the subject in the chest.

In statements taken immediately after the shooting, the officers had difficulty recalling specific events that took place, i.e., they seemed to have tunnel vision, could not recall how many rounds they had fired, or where their fellow officers were located and what actions they had taken. All of the involved officers experienced varying degrees of post-critical incident trauma.

The subject was later determined to have a history of mental problems.

Sergeant Dunlap used this incident to illustrate the necessity for proper training. Training must be aggressive, must duplicate as much as possible situations that the officers may encounter during the performance of their duties, and must be constantly updated.

He further observed that **many agencies are trying to buy success.** They look for a magic bullet or one combat course that will enable their officers to meet any and all challenges they face. Sergeant Dunlap's contention was that only constant

training will enable officers to shoot accurately when under stress. To win a gunfight, the officer has to hit the subject. Training is the means whereby officers learn the skills to accomplish this.

Summary of Remarks by
Sergeant Steve Robertson
Coordinator - Firearms Training
Indianapolis, Indiana Police
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Sergeant Robertson presented statistics from a study of 199 Indianapolis Police Department shootings to give an "end user" perspective on bullet performance and effectiveness.

Robertson summarized information obtained on these shootings from police reports, forensic examinations at the scene, autopsy reports, and a questionnaire submitted to all officers involved in shootings, from 1971-1987. Robertson characterized a typical shooting as close, dark, and fast, with subjects using cover much more frequently than officers. The study also disclosed that physical exertion often preceded officer-involved shootings, most often in the form of a foot chase or fight between officers and suspects. An average of 1-3 rounds were fired (revolvers were used throughout the study period) in each incident.

An examination of "lethality," or the percentage of fatalities to subjects shot was presented, where fatalities were broken down by the different types of departmentally approved ammunition used throughout the period. Ammunition varied from the .38 caliber 158 grain round nose lead bullet to the .357 125 grain scallop-jacketed hollow point. Robertson indicated that percentages were relatively constant until a change was effected in departmental firearms training from "conventional" target practice to reality based, combat-style training incorporating movement, time stress, and physical exertion. Since the inception of this new training program, fatal hits have increased from approximately 27% to 42%, often with the same ammunition. Robertson attributed the rise in the percentage of lethal hits directly to enhanced training.

Robertson presented a case study where 30 rounds were fired from a 9mm handgun at a subject seated in a vehicle. His examination of the results validated the information put forth in the 1987 Wound Ballistics Workshop. Rounds which struck in areas where the 9mm normally does not penetrate did not. Rounds which struck in areas where the 9mm normally does penetrate well did. Expansion of rounds recovered from the body was consistent with ammunition testing protocols in ballistic gelatin.

Robertson concluded that studies about wound, or terminal ballistics cannot be conducted in isolation. The variables of bullet construction, weapons used, number of rounds

fired, and the totally unpredictable nature of the "end user" must also be considered. Finally, and most importantly, unless shots are (1) Accurately placed, and (2) Penetrate deeply enough to cause serious trauma, all other issues become irrelevant.

Summary of Remarks by
Lieutenant Edward Fincel
Coordinator - Tactical Training Unit
California Highway Patrol (CHP)
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

Lieutenant Fincel's presentation centered around his agency's decision to replace revolvers with the Smith and Wesson 4006. Several shootings were discussed involving the 180-grain .40 caliber round now used by his department.

Fincel stated that since transitioning to the pistol, his 7,000-person department mandates monthly handgun and quarterly shotgun and rifle training. Fifty percent of all sessions are conducted at night. All training involves getting into, out of, and shooting around vehicles. Fincel stated that 98% of his department's shootings involve vehicles. The average distances involved was 38 feet. Fincel added that in eight shootings with the .40 caliber **where the subjects were struck in the torso,** all resulted in fatalities. In 13 others where extremities were struck, the subjects gave up. Fincel speculated that this may have been due to the large amount of tissue damage usually caused by this round.

Fincel indicated that the CHP's selection of the Smith and Wesson 4006 was based, in part, on ease of training, ease of operation with either hand, ease of one-hand reloading, and adaptability to different hand sizes.

Fincel indicated that the CHP historically used the 125 grain .357 and had experienced difficulty physically restraining some subjects after shooting them with this round. Fincel indicated that this round gave tremendous expansion but shallow penetration. These observations prompted the CHP's selection of the .40 caliber 180 grain hollow point as their service lead.

Fincel showed slides of several CHP shootings, all of which involved subjects in vehicles. Fincel made the observation that rounds which had passed through auto sheet metal and were recovered during autopsy showed expansion similar to results observed during bare gelatin testing. Fincel indicated that he had no explanation for this phenomenon. Fincel related another incident where a vehicle with a barricaded subject was engaged at 140 feet with the .40 caliber. In this case, Fincel indicated that there was inadequate penetration. Fincel added that .223 with 64 grain bullets and shotgun slug also failed to penetrate the vehicle at that distance.

Fincel cited a "hit ratio" of 45% for CHP shootings and credits this high percentage with department training which demands bulls-eye proficiency before moving to combat courses. Fincel indicated that the longer distances which typify CHP shootings demanded that trigger control and sight alignment be constantly reinforced through training if officers were to be effective at these distances.

Fincel concluded his remarks by saying that the CHP had reaffirmed the belief that **shot placement was the most important factor** in wound ballistics and that heavy bullets traveling slow had proven to be very effective in CHP shootings.

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Ballistician

Understanding Energy in Terminal Ballistics
by Duncan MacPherson
to the Wound Ballistic Seminar
FBI Academy, Quantico, Virginia
1/19-22/93

This presentation is an attempt to explain energy and energy effects in terminal ballistics to a lay audience. The observed lack of correlation between handgun bullet kinetic energy and tissue trauma is not a mystery requiring explanation, but is instead a result that is entirely compatible with physics and thermodynamics.

Simple physical examples (e.g., balls on a billiard table, a bullet fired into a tank of water) can be used as simple illustrations of energy effects that occur in more complex situations. A simplified thermodynamic analysis shows that almost all of the dynamic effect of kinetic energy is associated with some aspect of the wound cavity (temporary or permanent) before being transformed into thermal energy. Simple physical examples (e.g., a man jumping from a chair, a bullet fired into a tank of water) illustrate the lack of correlation between kinetic energy and damage in some physical processes; the reason for this lack of correlation is that physical damage is a result of stress (force per unit area), not energy. Higher kinetic energy usually increases the induced stress, but this stress only creates damage if it produces strains above the elastic limit; this physical situation is equally true for inanimate physical objects and body tissues. Perhaps the most obviously application of this process is in the use of body armor; wearing body armor does not change the bullet kinetic energy, but spreads the resultant force over a larger area to reduce the stress and associated strain (and damage) in body tissues.

Physicians have found that most body tissues have a relatively high elastic strain limit (i.e., well above the level produced by handgun bullet temporary cavities); this explains the observation that these tissues are not damaged by the temporary cavities produced by handgun bullets (temporary cavity tissue damage is much more likely from the higher strains resulting from the greater kinetic energy of some rifle bullets). Much of the kinetic energy of a bullet is associated with producing the temporary cavity volume (experiments have shown that these quantities are approximately proportional to each other); thus, the lack of correlation between handgun bullet kinetic energy and wound trauma is to be expected.

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UNDERSTANDING ENERGY IN TERMINAL BALLISTICS

Duncan MacPherson

ENERGY AND TISSUE TRAUMA

- LINEAR CORRELATION OF KINETIC ENERGY ABSORPTION AND DAMAGE
  - OFTEN ASSUMED AS SELF EVIDENT TRUTH
  - NOT TRUE IN MOST PHYSICAL PROCESSES
  - EVIDENCE SHOWS IT IS NOT TRUE IN TISSUE TRAUMA

- SUBJECT HERE IS EXPLANATION OF <u>WHY</u> TISSUE TRAUMA IS NOT PROPORTIONAL TO BULLET KINETIC ENERGY OR ENERGY ABSORPTION
  - NOT A MYSTERY
  - ENTIRELY PREDICTABLE FROM PHYSICS

KINETIC ENERGY ISN'T A FUNDAMENTAL PARAMETER

- MOST PEOPLE THINK IT IS, BUT THEN MOST PEOPLE AREN'T PHYSICISTS OR THERMODYNAMICISTS
- NEWTON'S LAWS OF MOTION DON'T MENTION ENERGY
- ANY ATTEMPT TO ANALYZE BULLET IMPACT USING ENERGY RELATIONSHIPS IS TECHNICALLY NAIVE
  - MOMENTUM IS CONSERVED IN ALL COLLISIONS
  - KINETIC ENERGY IS NOT CONSERVED IN ANY REAL COLLISION; AT LEAST SOME → HEAT
- NOT UNDERSTANDING ENERGY ONLY CAUSES TROUBLE WHEN SOMEONE WHO DOESN'T UNDERSTAND TRIES TO ANALYZE IT

FORMS OF ENERGY

- KINETIC ($\frac{1}{2}MV^2$)
- POTENTIAL (STORED IN SOME WAY)
- HEAT (THAT IS WHAT WE ARE GOING TO CALL IT)
- OTHERS THAT DON'T MATTER HERE (CHEMICAL IS USED TO OBTAIN BULLET VELOCITY)
- ALL FORMS OF ENERGY HAVE THE SAME UNITS (DON'T WORRY ABOUT IT)
- ENERGY CAN AND OFTEN DOES TRANSFER BETWEEN FORMS

ENERGY IN BULLET IMPACT

- KOCHER'S ANALYSIS - BULLET KINETIC ENERGY GOES TO:
  - HEAT
  - PROPELLING TISSUES OUTWARD (TEMPORARY CAVITATION)
  - CRUSH OF TISSUE (PERMANENT CAVITY)
  - BULLET DEFORMATION
- THIS ANALYSIS APPROACH IS NOT FRUITFUL, BUT EXAMINING IT IS EDUCATIONAL
- KOCHER THOUGHT THAT DETERMINING THE HEAT FRACTION OF THE TOTAL ENERGY IS DIFFICULT

ILLUSTRATIVE EXAMPLES OF ENERGY → HEAT

- BALLS ON A BILLIARD TABLE
- BULLET FIRED INTO A TANK OF WATER
- LEAD BULLET IN A FIXTURE ON THE BILLIARD TABLE
  - ENERGY IS NOT "USED UP" BY DEFORMATION
- UNDEFORMED BULLET INTO BLOCK OF WOOD

HEAT IS NOT AN INDEPENDENT ENERGY TERM IN BALLISTICS - IT IS JUST WHERE ALL THE ENERGY ENDS UP

ENERGY *ASSOCIATED WITH* BULLET DEFORMATION

- **BELIEF IN SIGNIFICANCE**
  - **COMMON**
  - **FALSE**

- **DEMONSTRATE BY DETAIL OR PRINCIPLE**

- **THERMODYNAMIC WORK = FORCE X DISTANCE**
  - **THERMODYNAMIC WORK IS AN ENERGY EQUIVALENT**
  - **BULLET DEFORMATION FORCE = TISSUE DEFORMATION FORCE**
  - **WOUND DEPTH > > BULLET SHORTENING**
  - **WORK (ENERGY) ASSOCIATED WITH BULLET DEFORMATION < < WORK (ENERGY) ASSOCIATED WITH WOUND**

BULLET ENERGY AND WOUNDING

- IT IS A LOT SIMPLER THAN KOCHER THOUGHT
- ALMOST ALL OF THE DYNAMIC EFFECT OF BULLET KINETIC ENERGY IS ASSOCIATED WITH SOME ASPECT OF THE WOUND CAVITY (TEMPORARY OR PERMANENT)
  - THIS ENERGY ALL → HEAT IN << A SECOND
  - 2300 FT-LBS OF ENERGY HEATS 3 LBS OF WATER 1°F
- UNFORTUNATELY, THIS INFORMATION IS NOT USEFUL IN ASSESSING WOUND TRAUMA

EXAMPLES ILLUSTRATING ENERGY AND DAMAGE

- BULLET FIRED INTO WATER TANK
  - WHERE IS THE DAMAGE?
- MAN JUMPING FROM CHAIR
  - HOW DOES HE LAND?
- BODY ARMOR
  - WOULDN'T YOU RATHER BE WEARING IT?

EQUATING ENERGY ABSORPTION AND DAMAGE IS CLEARLY WRONG

EQUAL IMPULSES GIVE A BULLET EQUAL δV

- IMPULSE = FORCE X TIME
- EQUAL EFFECT ON A BULLET IS NOT NECESSARILY AN EQUAL EFFECT ON TISSUE
- THINK ABOUT CAUSE OF DAMAGE

DAMAGE

- DYNAMIC DAMAGE IS DONE BY STRESS (FORCE PER AREA), NOT ENERGY

- FIRST EXAMPLE (BULLET INTO WATER)
  - WATER IS NOT DAMAGED BY HIGH FORCES OR HIGH STRESS

- SECOND EXAMPLE (JUMP FROM CHAIR)
  - FORCE (STRESS) MAGNITUDE DEPENDS ON LANDING MODE

- THIRD EXAMPLE (BODY ARMOR)
  - SPACIAL AND TEMPORAL SPREADING OF FORCE REDUCES THE TISSUE STRESS MAGNITUDE

- LARGER KINETIC ENERGY TENDS TO CAUSE LARGER FORCES, BUT THIS IS NOT ALWAYS TRUE

ENERGY, FORCE, AND DAMAGE

- ALL THE KINETIC ENERGY OF A NONPENETRATING BULLET IS ABSORBED BY THE TARGET
- ABSORBING THIS ENERGY PRODUCES FORCES ON, AND STRESSES IN, THE TARGET
- STRESSES IN THE TARGET ONLY CAUSE DAMAGE IF THEY PRODUCE STRAINS ABOVE THE ELASTIC LIMIT OF THE TISSUES INVOLVED
- MOST BODY TISSUES HAVE A RELATIVELY HIGH ELASTIC STRAIN LIMIT (i.e., WELL ABOVE THE LEVEL PRODUCED BY HANDGUN BULLET TEMPORARY CAVITIES)

SUMMARY

ANY ATTEMPT TO EQUATE BULLET KINETIC ENERGY AND BULLET EFFECTIVENESS IN CAUSING WOUND TRAUMA IS DOOMED TO FAILURE FOR TWO INTERCONNECTED REASONS

- **DAMAGE IS DONE BY STRESS (FORCE), NOT ENERGY**

- **AN INDETERMINATE, BUT USUALLY LARGE, FRACTION OF THE DYNAMIC EFFECT OF THE BULLET KINETIC ENERGY LEADS TO TISSUE STRESSES THAT ARE NOT LARGE ENOUGH TO CAUSE TRAUMA (ESPECIALLY IN HANDGUN LOADS)**

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